598.4
H73l

LEAD POISONING IN WATERFOWL
DOSAGE AND DIETARY STUDY

SUMMARY OF ILLINOIS NATURAL HISTORY SURVEY STUDY - 1948-1953

Conducted by Frank Bellrose and James Jordan

With Assistance From

Winchester-Western Division of Olin Corporation

NATURAL HISTORY SURVEY
1977
LIBRARY

JOINT REPORT OF
ILLINOIS NATURAL HISTORY SURVEY AND
OLIN CORPORATION, WINCHESTER GROUP

NOTICE: **Return or renew all Library Materials! The *Minimum* Fee for each Lost Book is $50.00.**

The person charging this material is responsible for its return to the library from which it was withdrawn on or before the **Latest Date** stamped below.

Theft, mutilation, and underlining of books are reasons for disciplinary action and may result in dismissal from the University.
To renew call Telephone Center, 333-8400

UNIVERSITY OF ILLINOIS LIBRARY AT URBANA-CHAMPAIGN

AUG 15 1994

DEC 14 1994

L161—O-1096

598.4
H73l
Nat. Hist. Survey

SOURCES OF INFORMATION

1. Files of Illinois Natural History Survey.
2. Reports by Frank Bellrose and James Jordan.
    - A. Shot Alloys and Lead Poisoning
      Jordan and Bellrose (1950)
    - B. Effects of Ingested Lead Shot Upon Waterfowl Population
      Bellrose (1951)
    - C. Lead Poisoning as a Mortality Factor in Waterfowl Population
      Bellrose (1959)
    - D. Influence of Diet in Lead Poisoning in Waterfowl
      Jordan (1968)

REPORT PREPARED BY: R. S. Holmes
Consultant for Olin

REPORT APPROVED FOR RELEASE BY: Glen Sanderson
Frank Bellrose
Illinois State
Natural History
Survey

Issued
February 1, 1975

TABLE OF CONTENTS

Page

I Summary 1

A. Background 1
B. Conclusions 1
C. Recommendations 8
D. Acknowledgement 9

II Introduction 11

III Scope of Files 13

IV Scope of Work 14

V Dietary Studies 16

A. Duck Pellets vs. Corn 16
B. Grains and Plants 17
C. Dietary Supplements 20
D. Food Consumption 21
E. Food Condition 22
F. Food Choice 25
G. Starvation Diet 27

VI Type of Duck 30

A. Domestic vs. Wild Mallard 30
B. Drakes vs. Hens 32
C. Adults vs. Juveniles 35

VII Toxicity and Recovery Rates 37

A. Food Intake vs. Weight Change 37
B. Weight Loss, Mortality and Food Intake 38
C. Rate of Shot Elimination 38
D. Pellet Dosage vs. Weight Loss 39
E. Recovery - Food Consumption 40
F. Recovery - Weight 40
G. Recovered Condition - Dosed vs. Non-Dosed 41

VIII Other Shot Metals 43

A. Antimony and Arsenic 43
B. Lubaloy Shot 44
C. Iron Shot 44
D. Lead-Calcium 45
E. Lead-Tin-Phosphorous 45

IX Disintegrating Shot 46

A. Lead-Magnesium Alloys 46
B. Powder Metal Feeding 49

gift - Natural Hist. Survey

Digitized by the Internet Archive
in 2021 with funding from
University of Illinois Urbana-Champaign

https://archive.org/details/leadpoisoninginw00holm

TABLE OF CONTENTS (CONTINUED)

CHARTS

1. Weight Loss vs. Mortality Domestic Mallards 52

2. Weight Loss vs. Mortality Wild Mallards 53

3. Chemical Composition of Dietary Materials 54

4. Food Consumption by Days, Weeks and Months 55

APPENDICES

A. Index for Illinois Natural History Files Located in Havana, Illinois 56

B. Summary of Experiments 64

I. SUMMARY

A. Background

During period of 1948-1953, a study of lead poisoning in waterfowl was conducted by Illinois State Natural History Survey at their Havana, Illinois Laboratory. Winchester and Western Cartridge Company, then Divisions of Olin Industries, assisted in this study. Although several papers based on this work were published by Frank Bellrose and James Jordan, no analysis of all the feeding experiments involved in the total program was ever done.

The Survey's Havana files on this work were made available to Winchester in May 1974. This report represents a summary of these files, covering 84 separate feeding experiments. Information taken from four Bellrose and Jordan publications as listed was also used.

Results of feeding experiments are summarized to show influence of shot dosage, (alloy, particle size, number or weight of pellets) type and amount of food, and dietary supplements on lead toxicity in ducks. Criteria for evaluation of toxicity was percent weight loss and mortality in a 30 day period. Initial tests were made with pekin ducks. Domestic and wild mallards were used interchangeably for major portion of program.

B. Conclusions

1. Dietary Studies

a. Duck Pellets vs. Corn

The first important discovery in the program was that pekin ducks would survive a large dosage of lead shot on a duck pellet diet (Protein 18%) and not on a corn diet (Protein 9%). A similar condition was found for Mallards (V.A.).*

---

*Indicates section of report as listed in index containing experimental data on this point.

b. Grains and Plants

Comparison of different diets showed susceptibility of both domestic and wild mallards to toxicity greatest for corn with a decreasing degree for mixed grains, weed seeds, rice, and wheat in that order. Supplementing a corn or grain diet with plants such as duckweed, sago pondweed and coontail greatly reduced and essentially eliminated toxicity for dosages as high as 4 #6 pellets in domestic mallards. Addition of plants to diet was of less benefit to wild mallards (V.B.).*

c. Dietary Supplements

Additions to a corn diet of egg albumen, oyster shell, calcium carbonate and phosphorous powder reduced degree of toxicity in domestic mallards by about 50% over a straight corn diet (V.C.)*

d. Food Consumption

Checks over a three month period showed wild mallards to consume an average of .15 lbs. of food per day and domestic mallards .21 lbs. Normally drakes consumed slightly more food than hens except during fertility and egg laying period when food consumption of hen increased fifty to one hundred percent. By second week following lead shot dosage food intake was reduced by as much as 80% depending on dosage and type of diet. The greatest reduction was for corn (V.D.)

---

*Indicates section of report as listed in index containing experimental data on this point.

e. Food Condition

Comparison of ducks on whole and ground corn diets showed weight loss and mortality starting at an earlier date after dosage for ducks on whole corn diet but no significant difference at end of 30 day period. Conclusion was that constituents in duck pellets as well as softness of food was responsible for lack of toxicity with this diet (V.E.).

f. Food Choice

Given a choice of grain and duck pellets domestic mallards showed a high preference for grain. After shot dosage they essentially quit eating grain and consumed a high amount of duck pellets as a means of survival (V.F.).

g. Starvation Diet

Reduction of available food for wild mallards given no dosage to same level as that being consumed by dosed ducks caused the same rate and degree of weight loss and mortality. This indicates that toxicity is directly related to amount of food consumed. The same weight loss occurred for dosed and undosed starved ducks in liver and kidney as well as in body (V.G.).

2. Type of Duck

a. Wild Mallard vs. Domestic Mallard

A one pellet dosage for wild mallards on a grain diet caused 20 to 40% weight loss and 50 to 100% mortality in 30 days. The same dosage caused little or no weight loss

and no mortality for domestic mallards. It was necessary to increase dosage to four pellets to cause same effect as one pellet in wild mallards.

Average weight of two types of ducks used in experiments was about same. There was a much higher variability in wild mallards. Lower mortality in domestic mallards was undoubtedly related to their higher food consumption (VI.A.).

b. Drakes vs. Hens

During most of year for a given dosage and diet mortality and weight loss for hens was about double that for drakes in both domestic and wild mallards. During fertility period, when food intake of hens almost doubles, susceptibility to toxicity is reduced being as low or lower than that for drakes (VI.B.).

c. Adults vs. Juveniles

Prior to having achieved full growth juveniles showed less toxicity than adults for a given shot dosage and diet. After achieving adult weight there was no difference (VI.C.).

3. Toxicity and Recovery Rates

a. Weight Loss, Mortality, and Food Consumption

For wild mallards on a corn diet given a one pellet dosage weight loss was 10-15% first week, 20-25% second week, 30-35% third week, leveling off the fourth week. Corresponding reduction in food consumption was 20-30% first week, 70-80% second and third weeks with an increase in fourth week. Mortality continued through fourth week and occasionally beyond that point.

Rate of weight loss and decrease in food consumption was less for ducks on other grain diets and for corn supplemented with plants (VII.A. & B.).

Increasing pellet dosage did not increase rate of weight loss for wild mallards on a corn diet. Ducks given a one pellet dosage showed same high rate of weight loss as those given 2, 3 and 4 pellets. Rate of weight loss and mortality of domestic ducks both increased as dosage was increased from 1 to 7 pellets.

b. Pellet Erosion

Rate of weight loss was shown to be closely related to rate of pellet or lead elimination. Ducks, mostly on corn diets, that showed a high rate of weight loss (35-40%) had eroded only 27% of the lead in 4 weeks while those on better diets with a slight weight loss (10-15%) had eroded 90% of the lead in the same period (VII.C.).

c. Recovery

For thirty days after dosage average daily food intake of dosed ducks that survived was only fifty percent that of non-dosed ducks. Following this 30 day period, food consumption of controls remained at same level. During fifth and sixth weeks after dosage survivors ate fifty percent more than controls, 25% more third week and same fourth week indicating recovery had been achieved (VII.E.).

This recovery period was confirmed in another test in which diet for dosed ducks was changed from grain to duck pellets at end of third week. Weight loss at this time was 30%. After four weeks on duck pellets, there was almost a complete weight recovery (VII.F.).

4. Dosages

a. Conventional Shot

Tests of the constituents in commercial lead shot, antimony, arsenic, and lead showed that in amounts present that toxicity was caused by lead, not antimony or arsenic (VIII.A.).

b. Other Types of Shot (VIII.A., B., C., & D.)

Shots tested included:

(1) Lubaloy (Copper Plated Lead)

Toxicity same as non-plated shot.

(2) Lead - 5% Calcium

Appeared to reduce degree of toxicity about 50% in domestic mallards.

(3) Lead-Tin-Phosphorous

Same as standard lead shot.

(4) Iron

No signs of toxicity in wild mallards given dosage of 10 pellets.

c. Disintegrating Shot (Lead-Magnesium)

With considerable difficulty three shot samples were prepared in East Alton shot tower containing .7, 1.1 and 2% magnesium. None of the shot would disintegrate in water. The 2% alloy showed faint fracture lines after 5 months immersion.

Feeding tests of .7 and 1.1% alloys to ducks on corn diet showed no reduction in toxicity over lead shot. Fluoroscope indicated some break up of pellets in gizzard shortly after dosing.

A 1 and 2 pellet dosage of the 2% magnesium shot and standard shot were given wild mallards on a diet of mixed grains and coontail. There was no mortality or significant weight change for 2% Mg shot while 2 pellet dosage of standard shot caused a 28% weight loss and 80% mortality. Fluoroscopic checks showed Magnesium shot to break up and leave gizzard between one and two weeks.

When tests were made comparing a one pellet dosage of the standard, and 2% Mg shot with coontail eliminated from grain diet there was no difference, both causing an 80% mortality. Pellet break up still occurred for Mg shot but duck failed to eliminate particles from system (IX.A.).

d. Metal Particles

X-ray tests on pekin ducks given large dosages of iron and lead particles showed rapid elimination of particles for ducks on duck pellet diet but failure to eliminate lead with corn diet.

Domestic mallards on corn diet were given dosages of lead and iron powder of three granulations, 10-14, 28-48 and 100-150 mesh. The ducks passed the two fine granulations of lead and all three granulations of iron with no signs of toxicity. Only the coarse lead particles (.06" avg. diameter) caused weight loss and mortality. This indicates that if shot is quickly broken into particles sufficiently fine by the gizzard they will be eliminated by a domestic mallard on corn diet with no toxic effect (IX.B.).

C. Recommendations

The following recommendations are made with respect to using information included in this report to develop, and evaluate a non-toxic shot that is more acceptable than soft steel as regards ballistics and gun wear.

1. The most promising approach for development of a non-toxic shot suggested by this study is based on information on the lead magnesium disintegrating shot and feeding tests of lead particles. There is evidence that a shot can be designed that will not break up in water but which will be disintegrated after ingestion by action of the duck's gizzard. There is also evidence that if lead is in sufficiently fine particles that the duck will pass it with no toxic effect even on a corn diet. These two findings, therefore, point to development of a disintegrating shot, predominantly lead, that will remain intact in the water environment, and in the duck's flesh, before and after cooking. Characteristics would be such that shot would be broken up by action of duck's gizzard into sufficiently fine particles that the duck will pass with no toxic effect regardless of diet. Available evidence indicates there is a good possibility of being able to accomplish this.

2. The influence of diet on toxicity, reduction in toxicity shown for oyster shell and calcium carbonate added to diet, and for 5% calcium in shot, along with strong evidence from Canadian work of antagonistic influence of iron in presence of lead, points up need for continuing studies to develop more basic information on factors influencing toxicity of lead in a duck's system. This could lead to finding an additive to lead shot having a similar antagonistic effect as iron, but in smaller quantities, making possible a higher density more ballistically efficient shot.

3. Report should be made available to experts in fields of toxicity and nutrition such as Cornell Veterinary School for their use in planning further studies that might lead to a better understanding and solution to the lead poisoning problem in waterfowl.

4. The large differences shown in susceptibility of domestic and wild mallards to lead toxicity, differences existing between hens and drakes which varies with time of year, greater resistance of juveniles to effect of lead until full growth, and influence of diet should all be carefully considered in planning tests to evaluate any new material proposed as a non-toxic shot.

D. Acknowledgement

The writer expresses appreciation to Illinois Natural History Survey, particularly Frank Bellrose and Glen Sanderson, for making available the files from which information was obtained for this report.

The writer was familiar with this program through his association with Frank Bellrose and James Jordan in the 1948-1953 period. This review of the files has brought back a better understanding and greater appreciation than existed when study was made of the thorough and excellent manner in which Jim Jordan and Frank Bellrose did their work. The detailed experimental records that they kept were most impressive.

If there had been a continuation of their effort beyond 1953 the writer firmly believes there would be a better solution to the lead poisoning problem today than soft steel or iron shot. Bellrose and Jordan demonstrated in 1950 that this was a possible answer, but with certain shortcomings still existing today.

After being associated with the problem off and on over a forty year period the writer firmly believes that with continuing effort along lines recommended above and with dedication and effort to the problem as exhibited by Bellrose and Jordan in the 1950 period that a solution better than steel shot can be found for the lead poisoning problem in waterfowl.

II. INTRODUCTION

In 1948 Western Cartridge Company, then a Division of Olin Industries, started support of a study of lead poisoning in ducks to be done by the Illinois State Natural History. Work was done at the Quiver Creek Laboratory of the Survey located in Havana, Illinois.

The study was supervised by Frank Bellrose with James Jordan then a Ph.D. candidate at University of Michigan working full time on the project. Dr. Harlow Mills, Chief of the Natural History Survey, also devoted considerable time to the study. The writer, then Manager of Ammunition Research and Development in East Alton, was responsible for directing the project for Olin with guidance from Charles S. Hopkins, Olin's Director of Conservation. The study covered the period from late 1948 until early 1953 with Olin's contribution to the Survey amounting to about $25,000 over this period.

Several papers were published by Bellrose and Jordan during and after this study was made, the major of which include:

1. 1950 - Shot Alloys and Lead Poisoning in Waterfowl - Jordan and Bellrose.
2. 1951 - Effects of Ingested Lead Shot Upon Waterfowl Population - Bellrose.
3. 1959 - Lead Poisoning as a Mortality Factor in Waterfowl Population - Bellrose (This is the Classic Publication which still serves as a bible of information on the lead poisoning problem.)

4. 1968 - Influence of Diet in Lead Poisoning in Waterfowl - Jordan (Paper started in 1952 with publication deferred for some unknown reason).

Frank Bellrose was brought back into Winchester's current non-toxic shot study in early 1974. He pointed out that Jordan had left the Survey in 1953 without completing analysis and reporting on all of the work Olin had supported. The files were still available in Havana and he agreed to loan them to Winchester. They were turned over to the writer in May. During the last few months effort has been spent on a low priority basis in sorting and analyzing their contents. This report is an attempt to summarize the pertinent information developed recognizing that there will be some duplication of that already published in the above listed papers. Actually, as noted, the four publications listed above were used to clarify and supplement data obtained from the files.

III. SCOPE OF FILES

The material as received from Bellrose was sorted into three sections as follows:

Section I — Index of Experiments

Files are marked 1-84 inclusive. They contain data, mainly weight change and mortality rate from 84 separate feeding experiments.

Section II — Files on Reports, Data Sheets and Charts

Includes thirteen files marked A-M inclusive. Material includes rough drafts of reports started by Jordan but never completed during course of the program, along with many tabulations and charts which are not in all cases identified as to experimental relationship. (Some of this material was included in Jordan's 1968 paper located after this review started.)

Section III — History of Ducks Used in Experiments

Includes eight files listing case history records of domestic and wild mallards captured and used in experiments.

Appendix A attached provides an index of the files. All material has been returned to Frank Bellrose.

IV. SCOPE OF WORK

The scope of work carried out is best shown by the description of the 84 experiments as listed in Appendix A. Pekin ducks were used in the first few experiments but majority of work was done with domestic and wild mallards. As a point of interest a count of ducks used in the 84 experiments show a total of 150 pekin, 818 wild mallards, 509 domestic mallards, and 101 other types of wild ducks making a total of 1,578. Some, particularly controls, were used in more than one experiment.

The general approach on each experiment was after proper conditioning to give one or more groups of ducks a specified dosage of a selected type shot and maintain a group of controls with no dosage. Ten ducks, five male and five female were generally included in each group but as noted there were exceptions to this. The principal variables investigated included:

1. Types and amount of dosage.
2. Types of food.
3. Dietary supplements.

After dosage ducks were weighed weekly. In some cases food intake was measured and in others, fluoroscopic examination made for presence of lead in duck's system. Degree of toxicity was determined by two indices, weight loss and mortality. Most of the tests were terminated after thirty days. Results of all experiments as summarized in this report are based on percent weight loss and percent mortality after 30 days. For ducks that expired prior to 30 days weight at time of death was carried in average through 30 day period.

In general there is a close relationship between percent weight loss and mortality during thirty day period. Chart 1 shows this relationship for all tests on domestic mallards and Chart 2 for wild mallards. Percentage mortality for a given weight loss appears to be somewhat higher for wild than for domestic mallards as shown by following taken from two charts.

	Percent Mortality	
Percent Weight Loss	Domestic Mallards	Wild Mallards
10	8	13
20	23	30
30	40	55
40	70	100

Appendix B tabulates for each of the 84 experiments showing where available and applicable the following:

1. Type and number of ducks in experiment.
2. Shot alloy, pellet size, and number of pellets given to duck.
3. Diet.
4. Weight loss and mortality after 30 days for dosed ducks and weight loss only for controls. (Note: There was no reported mortality for controls during 30 day test period.)

Results of experiments as shown in Appendix B and charts, graphs and tables in files, supplemented by information from Bellrose and Jordan's published reports were used to develop a summary on each of the many points related to toxicity of ducks that were investigated in this four year study.

V. DIETARY STUDIES

A. Duck Pellets vs. Corn

These experiments were carried out at beginning of program before individual tests were being indexed. Files were not clear on specific test data. Since results had a major influence on planning of subsequent experiments, tests on pekin ducks as reported by Bellrose and Jordan in their 1950 paper and by Jordan in his 1968 report are summarized below:

Test 1 - 5 Groups - 20 Each - Duck Pellet Diet

Dosage - Four groups given 20 pellets each of 4, 6, 8 & 10 sizes. Fifth group served as controls.

Results - (5 weeks) Ducks showed weight gain. Four died from enlarged liver. No signs of lead poisoning. Seventeen ducks sacrificed. Pathological examination showed excellent condition. Eroded pellets recovered from gizzard.

Test 2 - 46 Ducks Previously Dosed with 20 Pellets - Duck Pellet Diet

Dosage - Additional 10 pellets.

Results - (4 weeks) No evidence of lead poisoning.

Test 3 - 13 Ducks Previously Dosed with 30 Pellets

Dosage - 25 #4 Pellets

Diet - 7 on Corn
6 on Duck Pellets

Results - Six on corn diet died from lead poisoning, two on duck pellets died with cause not clear.

Test 4 - 15 Ducks - 5 Each Group

Group	History	Diet	Dosage	Mortality
1	No Previous Dosage	Corn	25 #4 Pellets	100% - Avg. 15.6 Days
2	Previous Dosage of 30 Pellets	Duck Pellets	"	None
3	No Previous Dosage	Corn	Controls	None

Thus there was a dramatic difference between susceptibility of pekin ducks to toxicity from large dosages of lead shot when on corn and duck pellet diets.

Subsequent tests were made to determine effect of duck pellet vs. corn diet on wild and domestic mallards. No direct comparative data on this could be found in files. Jordan's report states that a similar difference existed but quotes no specific data to show magnitude.

An analysis showing composition of duck pellet and corn diet as used in these experiments is shown in Chart 3.

B. Grains and Plants

1. Domestic Mallards

Following are results of tests of domestic mallards on various grain diets and grains supplemented by plants available in the Illinois River Valley. All were given a dosage of 4 #6 pellets.

	30 Day Results	
Diet	Weight Loss	Mortality
1. Corn	43%	70%
2. Tame Rice	10	20
3. Mixed Grains	30	30
4. Plant Seeds	19	20
5. Corn & Duckweed	8	20
6. Corn & Sago Pondweed	(+3)	0
7. Mixed Grain & Coontail	4	0

On another test the domestic mallards were given a dosage of 8 #6 pellets.

	30 Day Results	
Diet	Weight Loss	Mortality
Mixed Grain	34%	60%
Mixed Grain & Coontail	11	0
Corn and Duckweed	10	20

Susceptibility to lead poisoning appears to be greatest for ducks on corn diet with a significant reduction for rice, plant seed, and possibly the mixed grain diets. Addition of plants of various types appears to have greatly reduced and essentially eliminated toxicity for a 4 shot dosage and even for an 8 shot dosage. There was no mortality for diet with coontail added to mixed grain.

2. Wild Mallards

Similar feedings tests were made on wild mallards with dosage reduced to one pellet.

	Diet	30 Day Results	
		Weight Loss	Mortality
1.	Corn (Avg. 5 tests)	38%	72%
2.	Mixed Grain (Avg. 6 tests)	26	40
3.	Mixed Grain & Coontail	2	0
4.	Corn, Millet, Rice & Smartweed	35	60
5.	Corn & Coontail	30	40
6.	Corn, Rice & Seeds	20	20
7.	Corn and Alfalfa	30	40
8.	Mixed Grain and Rice	13	10
9.	Small Grain & Smartweed	(+5)	0
10.	Plant Seeds, 2 Weeks, Grain, 2 Weeks	30	60

As in domestic mallards there was a lower degree of weight loss and mortality for mixed grain than for a corn diet. Adding plants or seeds to corn diet reduced but did not eliminate mortality even with a one pellet dose. Weight loss and mortality were essentially eliminated with coontail added to a mixed or small grain diet.

Another series of feeding experiments were carried out with wild mallards using a four pellet dosage.

Diet	30 Day Results Weight Loss	Mortality
Mixed Grain & Coontail	26%	70%
Corn and Sago Pondweed	3	0
Corn and Coontail	38	60
Corn and Duckweed	29	60
Corn and Charro	36	70
Wheat	22	20

Under these conditions weight loss and mortality were eliminated only with sago pondweed added to corn diet. Degree of toxicity for wheat diet alone appears to be less than for corn or mixed grains alone.

C. Dietary Supplements

Experiments were carried out on several dietary supplements for which there was some evidence in literature that there might be an influence on lead toxicity. Tests were done only with domestic mallards. In first series dosage was 4 #6 pellets.

Diet	30 Day Results Weight Loss	Mortality
Corn - Shelled	43%	70%
Corn and Egg Albumen	23	20
Corn and Oyster Shell	18	20
Corn and Calcium Carbonate	20	20
Corn and Ascorbic Acid	37	70
Corn and Phosphorous Powder	17	20
Corn and $CaCO_3$ + P Powder	34	40

Corn oil was used to adhere each supplement to the shelled corn. The excessive amount of the supplement was discarded after the mixing operation.

With exception of ascorbic acid each of the above dietary supplements reduced weight loss and mortality to about fifty percent of that for corn alone but in no case was it eliminated.

Chart 3 attached shows composition of grains and various dietary supplements used in these experiments as determined by Department of Animal Nutrition at University of Illinois.

D. Food Consumption

1. Wild Mallards

Starting in May 1950 records were kept on food consumption for a group of wild mallards separated as hens and drakes. Daily consumption was noted for 10 days, weekly for 12 weeks, and monthly for 16 months. Results are shown on Chart 4. Average daily consumption per duck day was as follows:

Food Intake Per Duck Per Day (Pounds)

Period	Hens	Drakes
10 Days	.27	.16
12 Weeks	.13	.13
16 Months	.14	.15

High food intake for hens during first ten days probably was related to fertility and egg laying period. Although average consumption over 12 week and 16 month period was approximately the same for hens and drakes there were trends as shown on Chart 4.

2. Domestic Mallards

Records were kept of food consumption for a 15 day egg laying period starting April 25, 1950. Results by five day periods were:

Food Intake Per Duck Per Day (Pounds)

	Hens	Drakes	Diff. (%)
First 5 Days	.37	.22	60
Second 5 Days	.33	.19	59
Third 5 Days	.26	.16	61

Note high food consumption of hens during egg laying period as compared to drakes.

3. Wild Mallards vs. Game Farm Mallards

Records were shown by months for a three month period.

Food Intake Per Duck Per Day (Pounds)

Period	Wild Mallards	Domestic Mallards
Nov. 1950	.19	.22
Dec. 1950	.14	.21
Jan. 1950	.13	.19

The higher food intake of domestic mallards may account for their greater resistance to lead poisoning.

E. Food Condition

In view of differences in degree of toxicity of ducks on a whole corn and duck pellet diet experiments were carried out to determine if this was due to physical condition of food or its chemical composition. Domestic mallards were given a dosage of 6 #4 pellets on each of the following diets:

1. Whole Yellow Corn
2. Ground Corn
3. Duck Pellets

Results after 30 days were as follows:

Diet	Weight Loss	Mortality
Whole Corn	38%	70%
Ground Corn	30	60
Duck Pellets	30	40

Jordan in his 1968 report on this experiment comments as follows:

"By the end of the second week, four of nine birds on shelled corn had died, whereas only two of the nine on corn meal had succumbed. The food intake of latter group was 3.2 times"

Although Jordan concluded there was a difference in reaction of the ducks to the corn and ground corn diets, the criteria being used for evaluation in this report showed no significance at end of 30 days. Neither did diet of duck pellets show any large reduction in weight loss or mortality, for this particular experiment.

As a point of interest, information on this point was obtained from the Biometric tests run last year:

	Mortality in 30 Days	
Dosage	Whole Corn	Ground Corn
1 #6	20%	20%
3 #6	60	90
6 #6	80	90

Again there appears to be no significant difference in mortality after 30 days although data, as in Jordan tests, indicated that toxicity started at an earlier date for whole corn diet. Food consumption throughout 30 day period in Biometric tests was approximately the same for the two types of corn.

In another experiment Jordan measured rate of shot erosion as related to food consumption for domestic mallards on a whole and ground corn diet.

	Percent of Normal Food Consumption			Percent of Shot Eroded		
Weeks After Dosage	Ground Corn	Whole Corn	Difference	Ground Corn	Whole Corn	Difference
1	95	65	30	8	5	3
2	98	44	54	53	28	25
3	100	50	50	75	41	34
4	95	67	28	95	70	25

The above illustrates the greater activity of gizzard for ducks on a ground corn diet making possible a faster elimination of lead shot from system. There was no indication as to whether the difference was significant as regards effect on toxicity.

Although Jordan's conclusions were that ducks survived better on a ground corn then on a whole corn diet, data found in files in support of this are not conclusive and this was not found true in the Biometric tests.

F. Food Choice

One chart showed results of a test in which two groups of domestic mallards, one dosed with 4 #6 pellets and the other controls with no dosage were given a free choice of diet among whole corn, small grain, and duck pellets for a four week period. Weekly food consumption was as follows:

Food Consumption Per Day Per Duck (Pounds)

Period	Corn	Small Grain	Duck Pellets	Total
Controls				
First Week	.110	.025	.012	.147
Second Week	.110	.040	.005	.155
Third Week	.095	.015	.045	.155
Fourth Week	.110	.005	.013	.128
Avg. 4 Weeks	.106	.021	.019	.146
Dosed Birds				
First Week	.030	.025	.210	.265
Second Week	.065	.012	.210	.275
Third Week	.025	.013	.145	.183
Fourth Week	.025	.013	.090	.128
Avg. 4 Weeks	.035	.015	.164	.216

This experiment demonstrated preference of non-dosed ducks for a corn diet. The significant point shown, however, is how the dosed ducks immediately started eating a large quantity of duck pellets to offset effect of lead. No data on mortality and weight loss was found that could be associated with this experiment.

Results of another test were charted in which dosed and non-dosed domestic mallards were given a free choice between corn and duck pellets.

Food Consumption Per Day Per Duck (Pounds)	Corn	Duck Pellets	Total
Prior to Dosage			
Controls	.40	0	.40
Dosed	.37	0	.37
First Week After Dosage			
Controls	.28	0	.28
Dosed	.24	.01	.25
Second Week			
Controls	.35	0	.35
Dosed	.14	.02	.16
Third Week			
Controls	.32	0	.32
Dosed	.12	.04	.16
Fourth Week			
Controls	.20	.02	.20
Dosed	.10	.18	.28

Again controls ate corn and ignored duck pellets until fourth week. For some unknown reason the dosed birds did not start eating any appreciable amount of duck pellets until fourth week. No data was found to relate mortality and weight changes to these food consumption figures.

Results were shown for one other test in which wild mallards were given a choice of four foods. Total food consumption for a 30 day period was as follows:

	30 Day Consumption (Pounds)	
Food	Dosed Ducks	Controls
Tame Rice	6.2	13.0
Corn	.5	4.4
Smartweed Seeds	.7	1.0
Millet	.2	.1
	7.6	18.5

Rice appears to be a preferred food to corn for both controls and dosed birds as shown by this experiment.

G. Starvation Diet

Since food intake of ducks on a grain diet is greatly reduced after dosage, tests were made to determine effect on weight loss of food reduction alone as compared to dosed ducks. Daily food consumption was checked for wild mallards given a dosage of one #6 pellet. Two groups of controls were maintained. One was given the same amount of food each day consumed by the dosed ducks the previous day and the other an unrestricted supply. Diet was 80% small grain and 20% rice.

	30 Day Results	
	Daily Food Intake	Weight Loss
Drakes		
Dosed-Unrestricted Diet	.118 Lbs.	13%
Controls-Restricted Diet	.112 Lbs.	17%
Controls-Unrestricted Diet	.180 Lbs.	1%
Hens		
Dosed-Unrestricted Diet	.075 Lbs.	12%
Controls-Restricted Diet	.060 Lbs.	16%
Controls-Unrestricted Diet	.136 Lbs.	2%

Thus for both drakes and hens weight loss was essentially the same for non-dosed ducks on a restricted diet compared to ducks given a one pellet dosage and on a non-restricted diet.

In another test one group of wild mallard drakes was given a dosage of 1 #6 pellet and an unrestricted diet. The other group had their food intake arbitrarily reduced to 70% of the normal level. Two diets were used:

	Weight Loss %	
	Dosage-1 #6	Diet-70% Normal
Mixed Grain Diet		
1 Week	11	13
2 Weeks	24	16
3 Weeks	31	32
4 Weeks	33	40
Mixed Grain Plus Wild Seeds		
1 Week	4	11
2 Weeks	20	18
3 Weeks	28	31
4 Weeks	30	39

The forced reduction in diet again resulted in as much or more weight loss than the one pellet dosage.

Another chart was found which shows liver and kidney weight reductions as well as body weight caused by dosage and starvation.

				Percent Reduction	
	Control Ducks	Dosed Ducks	Starved Ducks	Dosed	Starved
Final Duck Weight (Lbs.)	2.3	1.2	1.2	48	48
Liver Weight (gms)	21.8	8.0	7.8	63	67
Kidney Weight (gms)	6.1	3.8	3.9	38	36

The starvation diet reduced organ weights as well as body weights by same amount as shot dosage.

VI. TYPE OF DUCK

A. Domestic vs. Wild Mallard

It was apparent from test data included in Section V that a wild mallard is more susceptible to lead poisoning than a domestic mallard. To better illustrate this the following comparisons are shown:

		Weight Loss (%)		Mortality (%)	
Diet	Dosage	DM	WM	DM	WM
Corn	1 #6	6	36*	0	68*
	2 #6	32	--	40	--
	4 #6	42	--	80	--
Mixed Grain	1 #6	1	30*	0	50*
Corn & Duckweed	4 #6	8	29	20	60
Corn & Pondweed	4 #6	(+3)	28	0	60
Mixed Grain & Coontail	1 #6	--	2	-	10
	4 #6	4	26	0	70

*Average of 5 tests

Thus, regardless of diet the domestic mallard (DM) shows a much lower weight loss and mortality rate for same pellet dosage than does the wild mallard (WM). In fact, it appears that a four pellet dosage for domestic mallards is required to produce the same degree of toxicity as a one pellet dosage in the wild duck.

Average weights were determined for 74 groups of ten each wild mallards (740 ducks) with 62 groups (620 ducks) of domestic mallards used in the experiments.

	Domestic Mallards	Wild Mallards
Average Weight for Groups of 10	2.65 Lbs.	2.71 Lbs.
Maximum Individual Group of 10	2.90	3.12
Minimum Individual Group of 10	2.30	2.10
Percent Over 3 Lbs.	0	10%
Percent Under 2.5 Lbs.	10%	22%

The above weights represent those at time of experiment. In essentially all cases both types of ducks had been kept in pens for varying lengths of time prior to start of experiment and generally maintained on a duck pellet diet. Under these conditions average weight of wild mallards as used in experiments was higher and variation from group to group much greater.

As reported in previous section average food consumption over a three month period averaged .153 lbs. per duck per day for wild mallards and .173 lbs. or 13% higher for domestic mallards. This may be a factor in their greater resistance to lead toxicity.

Jordan in his 1968 paper shows a direct comparison between toxicity and food consumption for the two types of ducks. Tests were conducted in February 1950 with diet of small grains. Each group consisted of ten hens and ten drakes.

	Controls		Dosed-1 #6	
	DM	WM	DM	WM
Initial Weight (Lbs.)	2.93	2.68	2.98	2.61
Avg. Daily Food Intake (Lbs.)	.165	.140	.185	.090
Weight Loss (%)	4	0	0	25
Mortality (%)	0	0	0	40

In this particular test initial weight was greater for the domestic mallards. Food consumption for these ducks was 18% higher for controls and 100% higher for dosed birds. Domestic ducks showed no effect of the one pellet dosage as contrasted to a 25% weight loss and 40% mortality for wild mallards.

B. Drakes vs. Hens

1. Domestic Mallards

Additional information if desired on this point could be obtained by a more detailed analysis of the individual experiments since in most cases the group of 10 ducks consisted of 5 Hens and 5 Drakes.

Jordan did make this analysis on Experiment #10 carried out in January 1949. Domestic mallards on a corn diet were given variable dosages from 1 to 7 #6 pellets. The hens suffered a mortality rate of 64% and drakes 36%.

A test was made in July comparing the two sexes at each of three age levels. Diet was mixed grain and dosage was 8 #6 pellets.

	Weight Loss (%)		Mortality (%)	
Duck Age	Drakes	Hens	Drakes	Hens
Adult	27	38	60	60
Juvenile-8 Weeks	2	4	0	0
Juvenile-5 Weeks	8	25	20	40

Difference between indicated degree of toxicity was hardly significant except possibly for the young juveniles. Another test was made in February 1950 with dosage reduced to one pellet. There was no mortality or weight loss for either sex.

As reported in previous section, food intake of domestic mallard hens increased more than 50% over that of drakes during the egg laying period. No specific test data was found on this but Jordan in his 1966 paper states that in this same period a total of 16 out of 31 drakes (41%) died from a given shot dosage and only 6 out of 41 hens (15%) died.

2. Wild Mallards

Results of three separate direct comparisons were found:

Time of Year	Dosage	Diet	Weight Loss M	Weight Loss F	Mortality M	Mortality F
February 51	1 #6	Mixed Grain	18	29	10	50
April 51	1 #6	Mixed Grain	36	32	60	20
October 49	1 #6	Grain & Coontail	(+3)	7	0	20
October 49	2 #6	Grain & Coontail	23	28	50	80

Note that in February weight loss and mortality were greater for the hens but in April the reverse was true. Again this may be related to fertility and egg laying period. In October with a better diet the hens again appeared to show a slightly higher degree of toxicity for both dosages.

Jordan also reports on a more detailed analysis made in fall and winter months of 1949. Combined results of three experiments, showed that for dosages of one and two pellets, 27 drakes had a mortality rate of 22% and 30 hens a rate of 50%. The following taken from a chart found in file probably represents these same experiments.

Weeks Following Dosage	Mortality Rate (%) Hens	Mortality Rate (%) Drakes
1	3	0
2	16	0
3	32	7
4	43	20
5	50	22

Not only did the hens show a much greater degree of mortality for a given lead dosage at conclusion of experiments, it occurred at a much faster rate.

He also reports on a control test conducted in February 1951 comparing two sexes in which food intake as well as weight change and mortality were noted. Diet was small grain and dosage 1 #6 pellet.

	Drakes		Hens	
	Controls	Dosed	Controls	Dosed
Initial Weight (lbs.)	2.94	2.82	2.40	2.40
Avg. Daily Food Intake (lbs.)	.15	.10	.13	.08
Weight Loss (%)	0	20	(+1)	30
Mortality (%)	0	10	0	50

Hen weight was about 15% less than that of drakes and food consumption for both control and dosed ducks was lower by about same percentage. The hens again appear to show a greater susceptibility to effect of lead. This may have been related to lower initial weight and less food consumption.

C. Adults vs. Juveniles

1. Domestic Mallards

A test was made in July and August 1949 comparing three age groups. Diet was mixed grains and dosage 8 #6 pellets.

	Weight		
	Initial	Loss	Mortality
Adults	2.6 Lbs.	33%	60%
Juveniles-8 Weeks	2.3 Lbs.	0	0
Juveniles-5 Weeks	1.2 Lbs.	16	30

The adults showed a significant degree of toxicity whereas the 8 week juveniles appeared to have resisted effect of the 8 pellet dosage. Jordan commented that for the 5 week juveniles the damage from lead was probably secondary to the influence caused by nutritional deficiencies as a result of their being on a grain only diet during a rapid growing period in their lives.

2. Wild Mallards

Three experiments were conducted using captured adult wild mallards and juveniles estimated to be 7-8 months old. Dosage was 1 #6 pellet in all cases.

		Weight		
	Diet	Initial	Loss	Mortality
1. Jan. 1950				
Adults	Mixed Grain	2.75 Lbs.	34%	80%
Juveniles	Mixed Grain	2.66 Lbs.	29	60
2. Dec. 1951				
Adults	Mixed Grain	2.94 Lbs.	26*	20
Juveniles	Mixed Grain	2.23 Lbs.	8*	0

		Weight		
	Diet	Initial	Loss	Mortality
3. Dec. 1951				
Adults	Wheat	3.17 Lbs.	18	10
Juveniles	Wheat	2.84 Lbs.	27	20

*Adjusted for control change.

Difference did not appear significant in Tests 1 and 3 where weight of juvenile approached that of the adult. However, in Test 2 where juveniles had not reached their full growth they appeared to resist effect of one pellet dosage better than the adult.

VII. TOXICITY AND RECOVERY RATES

Additional information on this subject could be developed by a more detailed analysis of individual experiments. Most data sheets show by weeks weights of both controls and dosed ducks for 1 to 3 weeks prior to dosage and mortality and weights of surviving ducks by weeks up to four and sometimes as long as six to eight weeks following doage. As mentioned previously, to simplify this presentation only weight loss and mortality at four weeks, or thirty days, after dosage was used in evaluating results of most experiments.

There were in the files several drafts of charts and graphs prepared by Jordan supplying miscellaneous information relating to toxicity and recovery rates. Details of conditions involved in experiments were not available in all cases.

A. Food Intake vs. Weight Change

Dosage was one #6 pellet for wild mallards. Tests were made with both corn and small grain diets. Food reduction represents percent change from a normal diet.

	Corn Diet		Small Grain Diet	
Weeks Following Dosage	Food Reduction	Weight Loss	Food Reduction	Weight Loss
First	23%	8	9	4
Second	82	22	40	9
Third	73	33	33	11
Fourth	43	33	22	12

Note that both amount of food reduction, which was voluntary, and weight loss were greater for corn than for small grain diet. After third week food intake increased and weight loss stopped. Probably most of pellets had been eliminated at this time.

B. Weight Loss, Mortality and Food Intake

Following is average for measurements of these three conditions from several tests of wild mallards given a dosage of 1 #6 pellet. Diet was not specified but was probably corn or mixed grains.

Weeks After Dosage	Decrease In Food Intake	Weight Loss	Mortality
1	35%	15%	0%
2	35	27	23
3	20	30	34
4	30	30	60

Note that food intake started to increase after third week. Weight loss ceased but mortality continued because of weakened condition of ducks.

C. Rate of Shot Elimination

Ducks, wild mallards, were divided into two groups, sixty which had shown only a slight loss in weight during four weeks of experiment, and 53 for which loss was moderate to severe. Cause of difference in weight loss was not specified but was undoubtedly a combination of dosage and diet. Amount of shot left in duck was determined concurrently with weight checks.

Weeks After Dosage	Percent of Shot Eroded and Eliminated (From Gizzard) Slight Weight Loss	Moderate to Severe Weight Loss
1	5	0
2	37	4
3	65	12
4	90	27

Elimination was, of course, much faster for ducks showing only a slight weight loss.

D. Pellet Dosage vs. Weight Loss

Wild mallards were divided into two groups, 53 which had been given a one pellet dosage and 19 given from 2 to 4.

Weeks Following Dosage	Average Weight Loss Dose 1 Pellet	Dose 2, 3 or 4 Pellets
1	10	8
2	25	20
3	34	32
4	39	38
5	40	42

A one pellet dosage as shown previously will generally cause an 80-100% mortality in 30 days for wild mallards on a grain diet. Increase in dosage did not increase rate of weight loss.

E. Recovery - Food Consumption

Wild mallards were divided into two groups. One consisted of 15 controls and the other 23 dosed birds which had shown a large weight loss but survived the 30 day test. Both groups were given an unlimited supply of food, type not specified, and daily intake measured.

	Average Daily Food Intake (Pounds)	
Diet	Controls	Dosed
During Experiment	.149	.076
First Week of Recovery	.168	.257
Second Week of Recovery	.164	.266
Third Week of Recovery	.147	.206
Fourth Week of Recovery	.168	.171

Note that food consumption by dosed birds during first two weeks of recovery period was 50% higher than controls and by fourth week was reduced to same level, at which time they had probably recovered from effect of dosage and regained their normal weight.

F. Recovery - Weight

A group of 12 adult drake wild mallards were dosed with 1 #6 pellet. Diet was grain until 28th day when it was changed to duck pellets. There was still some evidence of shot in the gizzard at time diet change was made.

Week After Dosage	Diet	Weight		
			Changes	
		Average	Weekly	From Start
Start	-----	2.95 Lbs.		
First	Grain	2.86	-5	-5
Second	Grain	2.40	-14	-15
Third	Grain	2.10	-12	-29
Fourth	Grain	1.90	-10	-35
Fifth	Duck Pellets	2.45	+29	-13
Sixth	Duck Pellets	2.67	+5	-9
Seventh	Duck Pellets	2.75	+3	-7

Weight loss was approximately same as shown in other experiments for wild mallards on corn diet given one pellet dosage. Change in diet even though lead was not yet completely eliminated resulted in a rapid recovery, weight coming back almost to normal level by end of second week.

G. Recovered Condition - Dosed vs. Non-Dosed

Two groups of wild mallards, one of which had never been dosed and the other which had recovered from a dosage of lead, were placed in pens and given no food for a 25 day period.

Days Without Food	Average Weight Loss	
	Recovered From Dosage	No Previous Dosage
7	20	18
14	31	32
21	42	43
25	51	50

Conclusion from this experiment was that ducks that had recovered from lead shot were no more susceptible to influence of food shortage in wild than those that had never ingested any shot. Records are shown for hens and drakes in both groups and there were no differences.

VIII. OTHER SHOT METALS

Much of the information summarized in this section was reported in the 1950 Bellrose-Jordan paper.

A. Antimony and Arsenic

One of the early tests made using pekin ducks was to determine effect of the constituents in lead shot. Results as taken from Jordan-Bellrose report were as follows. Ducks were on a corn diet.

		48 Day Results	
Ducks	Dosage	Weight Loss	Mortality
18 Adult	Pure Lead-30 #6 Pellets	24	100
12 Adult	None - Control	8	17
21 Juv.	Pure Lead-30 #6 Pellets	15	38
10 Juv.	None - Control	3	20
12 Juv.	.049 Gms Arsenic (Equiv. 42 Pellets)	7	25
12 Juv.	.065 Gms Antimony (Equiv. 13 Pellets)	8	8
12 Juv.	None - Control	5	17

Although there was some mortality in all cases, even among the controls, conclusion was that lead is the predominant factor and effect of arsenic and antimony is negligible. Examination of deceased ducks shows that mortality for the controls and those given arsenic and antimony was due to causes other than metallic poisoning. The 48 days on a straight corn diet may have been a contributing factor.

B. Lubaloy Shot

Lubaloy is a Trade Mark used by Winchester for a copper plated lead shot. It was recognized that the plating would be removed by action of the duck's gizzard but it was thought that it might delay the time when lead starts to dissolve in the gizzard and provide a short period during which the pellets could be eliminated from the gizzard while the gastrointestinal tract was still functioning normally. Following are results of tests comparing plated and unplated shot. Domestic mallards on a corn diet were used:

	Standard Lead Shot		Lubaloy Shot	
Dosage	Weight Loss	Mortality	Weight Loss	Mortality
1 #6	-6	0	-4	0
3 #6	-32	40	-17	33
5 #6	-36	60	-40	100

Conclusion was that the copper plating is of no value in reducing lead toxicity.

C. Iron Shot

Western Cartridge Company was, during this period, pursuing the development of soft iron shot, not for purpose of resolving the lead poisoning problem, but for economic reasons in view of increasing lead price following end of World War II and concern about a world shortage. Samples of shot were provided Bellrose for testing.

In one case domestic mallards on corn diet were given six #6 pellets and showed no mortality or significant weight loss in thirty days. In another, wild mallards were given ten #6 iron pellets and results were the same.

D. Lead Calcium

There were literature references stating that presence of calcium might eliminate or minimize lead toxicity. No attempt was made to form shot but a 5% calcium lead alloy was cut into pieces approximating a #6 pellet. Domestic mallards on a corn diet were fed varying amounts of these pellets along with standard lead shot.

	30 Day Results	
Dosage	Weight Loss	Mortality
6 #6 Lead Pellets	43	80
.22 Gms. Ca-Pb Pieces Equiv. 2 #6	22	50
.44 Gms. Ca-Pb Pieces Equiv. 4 #6	20	50
.88 Gms. Ca-Pb Pieces Equiv. 8 #6	31	50

There was some evidence that presence of calcium reduces lead toxicity but this alloy was not pursued further because of problems of making a calcium-lead alloy shot.

E. Lead-Tin-Phosphorous

A patent had been issued claiming this alloy to be non-toxic. No information could be found on exact composition. Tests of domestic mallards on a grain diet given 6 #6 pellets showed a 43% weight loss and 80% mortality demonstrating this alloy to be just as toxic as standard lead shot.

IX. DISINTEGRATING SHOT

A. Lead-Magnesium Alloys

The idea of a disintegrating lead-magnesium shot to solve the duck lead poisoning problem was first conceived by Professors Dowdell and Green of University of Minnesota in the mid-thirties. They claimed that an alloy containing 2% magnesium will break up into fine particles in a few days in water, making it difficult or impossible for a duck to pick up, and if ingested by ducks, breaks up into fine particles in 24-48 hours that ducks will pass with no toxic effect.

A major part of the early Bellrose program was an attempt to confirm Dowdell's and Green's claims that a 2% magnesium-lead alloy would solve the lead poisoning problem in ducks. Considerable time and money were spent attempting to make a lead-magnesium alloy shot in the East Alton shot tower. Three small lots were eventually made containing .7, 1.1 and 2% magnesium. It was evident that there were still many problems involved in developing a suitable manufacturing process for lead-magnesium shot but regardless of this, samples of the three alloys were given to Bellrose for testing.

Reports of these tests as covered in the 1950 Bellrose-Jordan paper supplemented by information from the files are summarized below.

1. Disintegration Rate

Results are reported only on the 2% magnesium shot. There was no change in shape or size of the pellets after 5 months immersion in water. There was evidence of faint fracture lines

showing some signs of a reaction. Drop tests of pellets after 14 days immersion indicated that ordinary movement of water would be insufficient to break down pellets left in bottoms of sloughs, lakes or marshes.

2. Feeding Tests

   a. .7% Magnesium Alloy

      (1) Ten pekin ducks on duck pellet diet dosed with 10 #6 pellets showed no apparent effect after 2 months. Radiographs of gizzard and intestines revealed a disintegration of pellets in gizzard between 9 and 48 hours after dosing. Lead particles and dust remained after 72 hours.

      (2) Six pekin ducks on corn diet dosed with 4 #7 1/2 pellets showed 50% mortality in 3 weeks. Small amounts of lead still in gizzard after 6 days. Results were essentially the same for ducks given 4 #6 standard lead pellets.

   b. 1.1% Magnesium Alloy

      (1) Pekin ducks - Corn diet. Results same as for .7% alloy.

      (2) Wild mallards (juveniles 5-6 months) - Corn diet.

Dosage		30 Day Results	
		Weight Loss	Mortality
Standard Lead Shot	1 #6	-40	80
1.1% Mg Shot	1 #6	-30	90
	2 #6	-36	100
	3 #6	-35	100
	4 #6	-43	100

No information was provided as to whether break up occurred in gizzard. Regardless of this there appeared to be no reduction in toxicity with 1.1% Mg shot.

c. 2% Magnesium Alloy

Shot pellets of this alloy along with standard lead shot were fed to wild mallards on two different diets.

	Dosage			
Alloy	Size	No.	Mortality	Weight Change
Mixed Grain and Coontail Diet				
2% Mg	8	1	0	+2%
2% Mg	8	2	0	+2%
Std. Lead	6	1	30	-7%
Std. Lead	6	2	80	-28%
Mixed Grain Diet				
2% Mg	8	1	80	-30%
Lead	8	1	80	-30%

Ducks were fluoroscoped weekly. With mixed grain-coontail diet essentially all signs of the 2% Mg shot had disappeared from the duck's gizzard between one and two weeks. Mortality was eliminated and weight loss less than for ducks on same diet given corresponding dosages of standard lead shot. When diet was changed to mixed grain only toxicity was equivalent to that for lead shot. Examination of deceased ducks, death occurring in 2 to 4 weeks, showed some pellet break up but failure of particles to leave system.

Thus there is evidence that a 1-2% magnesium-lead alloy that does not break up in water, will be broken up by action of gizzard, but that passage of broken particles without toxicity is dependent on diet.

B. Powdered Metal Feeding

To investigate further the principle of resolving the toxicity problem by shot break up in gizzard a series of tests was carried out feeding ducks varying dosages of granular or powdered metals.

1. Pekin Duck Tests

No information on these tests was located in files but because of their significance they are summarized from Jordan's 1968 report. Three pekin ducks were used.

Duck #1 - Placed on duck pellet diet and given dosage of lead powder equal in weight to 10 #4 pellets.

Duck #2 - Placed on corn diet and given same lead powder dosage.

Duck #3 - Placed on corn diet and given same weight dosage of iron powder.

Ducks were X-rayed at 4 hour intervals for first 24 hours and at daily intervals thereafter. Results were reported as follows:

Duck #1 - At four hours elimination of lead had started, amount decreased progressively during next 20 hours and at 24 hours only a small amount of lead remained. At 48 hours all lead dust eliminated.

Duck #2 - At four hours elimination similar to Duck #1 but during next 20 hours rate decreased with still

considerable amount in gizzard after 24 hours. There was some further elimination during next few days with considerable amount still present on fifth day and duck died on seventh day.

Duck #3 - All iron powder eliminated from gizzard and intestine at end of 48 hours.

This experiment certainly demonstrated the dramatic effect of diet on lead powder elimination and difference between lead and iron. There was no information supplied on granulation of powder used in experiment.

2. Domestic Mallard Test

Domestic mallards on a corn diet were given .67 grams (equiv. 5 #6 shot) of lead and iron powder of varying granulations. Three ducks were given each indicated dosage.

Dosage		30 Day Results	
		Weight Loss	Mortality
Lead Powder -	10- 14 Mesh	38	100
	28- 48	7	0
	100-150	9	0
Iron Powder -	10- 14 Mesh	0	0
	28- 48	4	0
	100-150	7	0

Only the coarse lead powder of an approximate .06" average diameter (#11 shot) showed any significant degree of lead poisoning as measured by mortality and weight loss. Lead particles finer than 28 mesh, approximate .02" diameter, passed with no apparent toxic effect. No information was found on X-ray or fluoroscopic checks made on metal powder passage.

Thus there is evidence in this test that domestic mallards will pass lead powder sufficiently fine even on a corn diet with no apparent toxic effect.

3. Wild Mallards

Three wild mallards on corn diet were given .80 grams (equiv. 4 #4 pellets) of 1.1% lead magnesium alloy broken into pieces. Two wild mallards on same diet were given .80 grams of lead powder and two others the same quantity of iron dust.

	30 Day Results	
Dosage	Weight Loss	Mortality
.80 gms. Pb-Mg Pieces	36	100
.80 gms. Pb Powder	36	100
.80 gms. Fe Powder	10	50

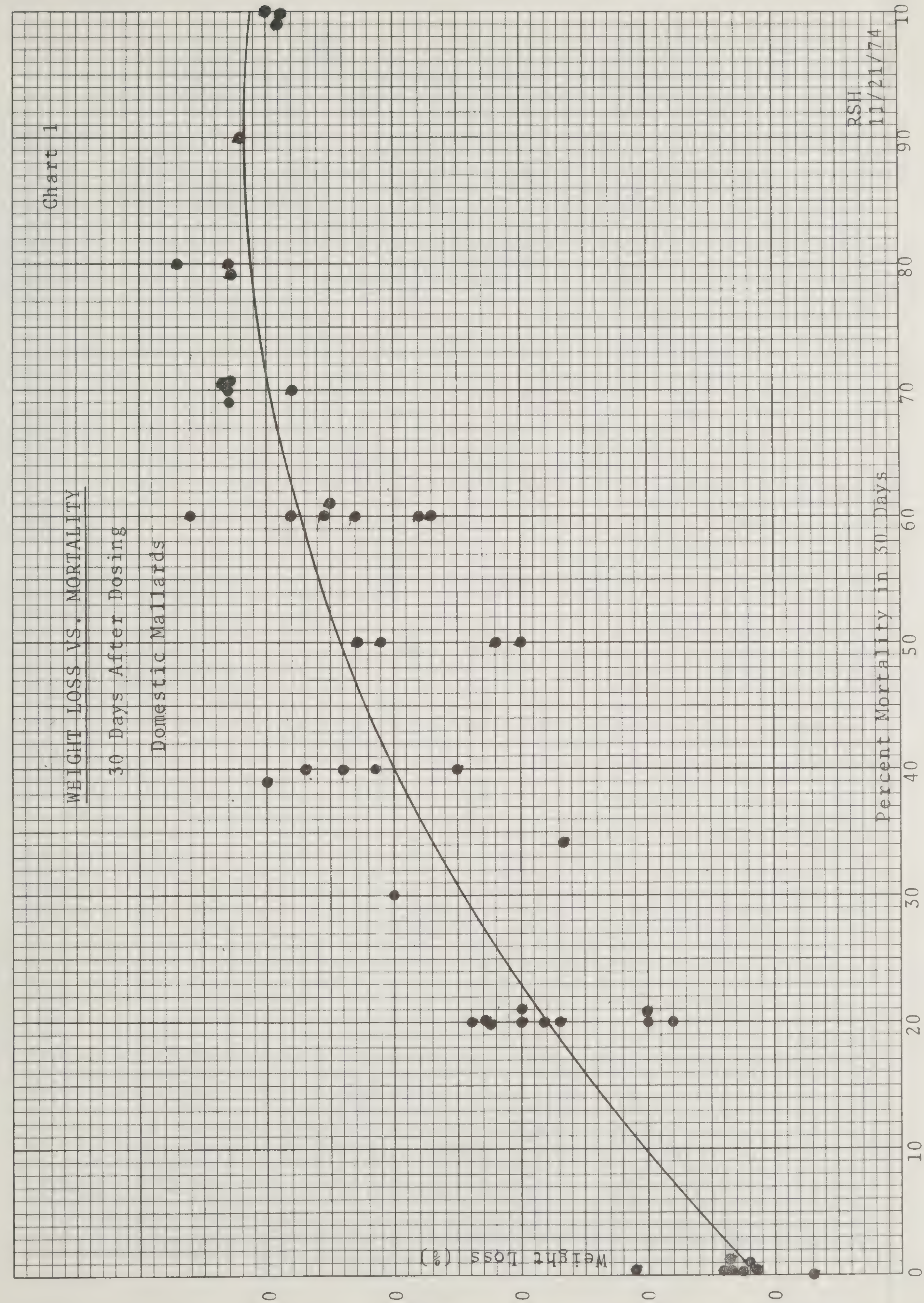
There was no explanation for death of the one duck given iron powder. Likewise there was no information on granulation of powders used.

Concluding, Bellrose's powdered metal feedings indicate that diet and granulation are important factors in controlling the duck's ability to pass lead powder without toxic effect. The fact that one group of domestic mallards passed powdered lead of a known granulation when on a corn diet with no mortality or significant weight loss appears to be sufficient justification to pursue the study of a shot that disintegrates in the duck's gizzard as a solution to the lead poisoning problem.

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

Chart 1



NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

EUGENE DIETZGEN CO.
MADE IN U. S. A.

Chart 2

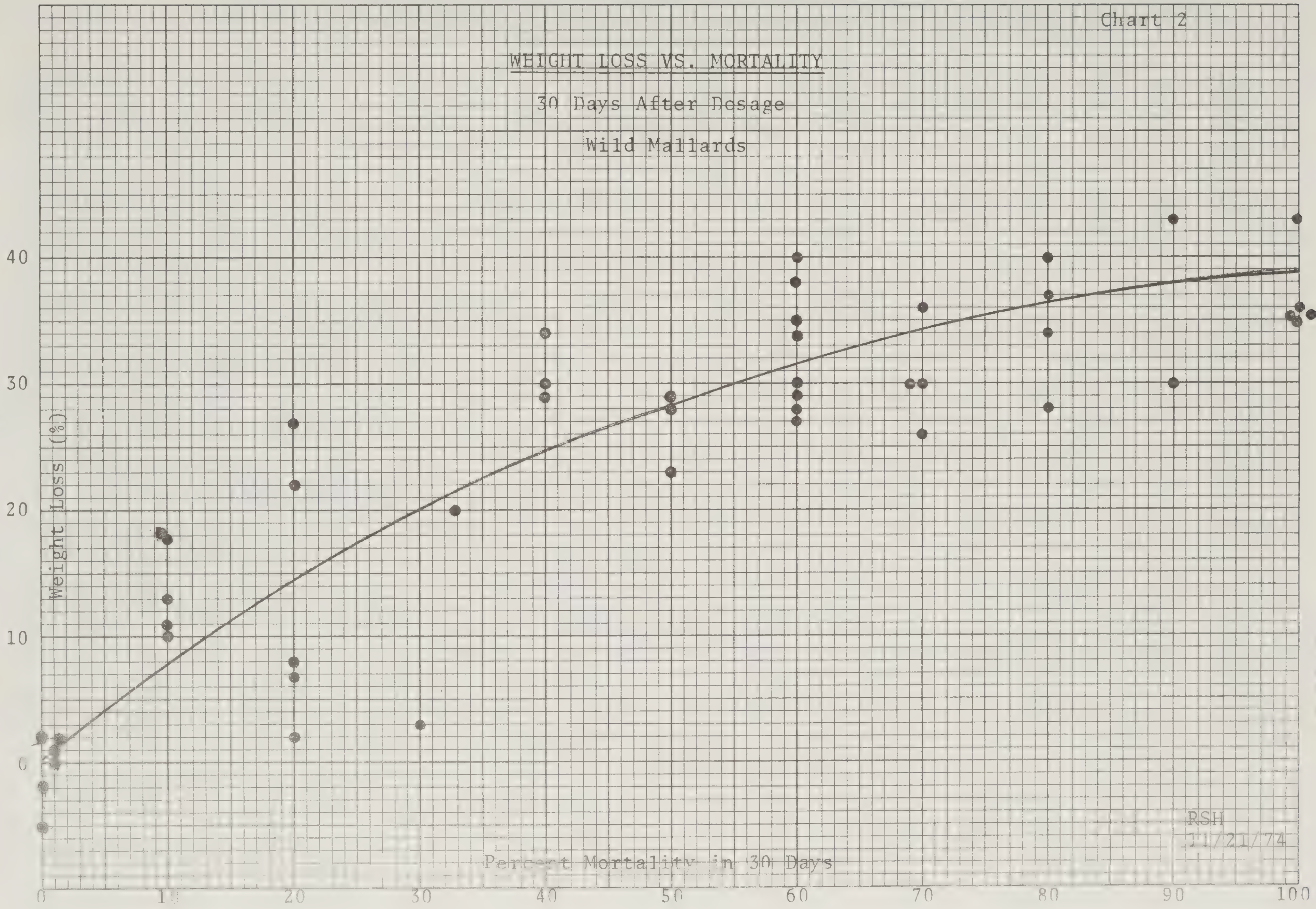


Chart 3

ANALYSIS OF FOODS BY DEPARTMENT OF ANIMAL NUTRITION

UNIVERSITY OF ILLINOIS

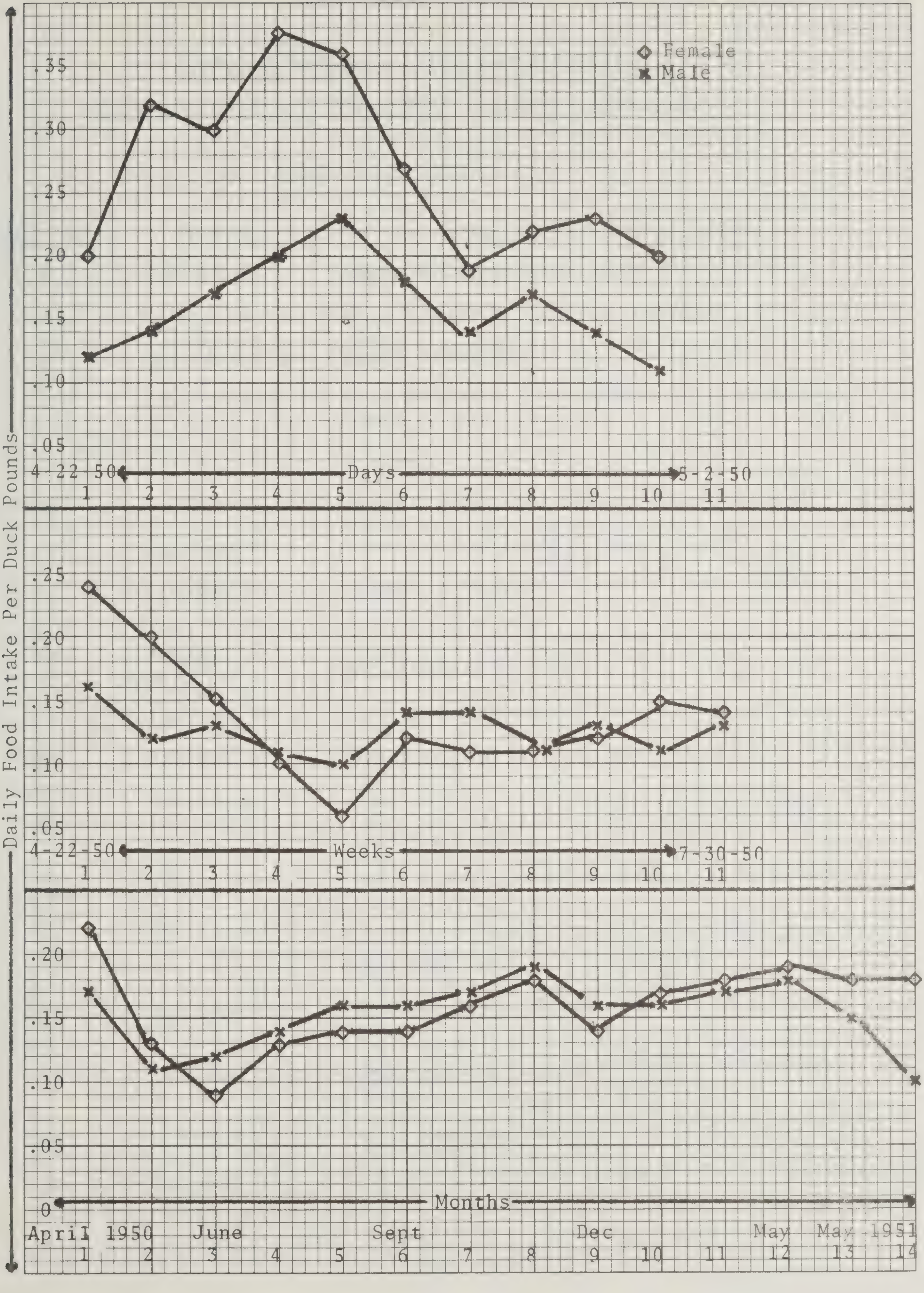
Lab. No.	Sample	Date	Dry Matter	Ether Extract	Crude Protein	Total Nitrogen	Ash	Calcium	Phosphorous
			%	%	%	%	%	%	%
49-245	Coontail	4-26-49	90.03	0.733	12.31	1.97	14.45	1.96	0.156
49-246	Mixed U. S. Grain Used as Duck Feed	"	89.62	3.04	13.50	2.16	8.50	0.111	0.444
49-247	Red Comb Duck Mash Pellets	"	91.55	3.65	18.88	3.02	7.45	1.47	0.754
49-248	Yellow Corn Collected From U. S. Grain Inspection	"	89.59	4.81	9.31	1.49	1.48	0.084	0.350
49-249	Large Seed: Smartweed, Polygonum Pennsylvanicum	"	90.45	2.70	7.62	1.22	2.48	0.181	0.282
49-250	Barnyard Grass, Echinochloa Crusgalli (Wild Millet)	"	92.31	3.12	9.50	1.52	6.29	0.302	0.393
49-310	Duck Weed, Very Moist Partly Dried	6/7/49	88.87	1.91	18.06	2.89	15.47	2.03	0.708
49-311	Millet, 2nd Lot	"	-----	----	9.38	1.50	6.18	0.232	0.343

Chart 3

JRBa
7-2-49

FOOD CONSUMPTION

Chart 4



EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH

Appendix A

ILLINOIS NATURAL HISTORY SURVEY FILES

COVERING OLIN SPONSORED WORK IN PERIOD 1948-1953

I. INDEX OF EXPERIMENTS

Exp. No.	Period	Description of Experiment
1,2,3	Sep-Dec 48	Initial Experiments with Pekin Ducks
4	Nov 48-Jan 49	Wild Mallards - Magnesium Alloy Shot
5	Dec 48-Feb 49	Pekin Ducks Given Pb, Fe, Ca Dust Particles
6	Jan-Feb 49	Wild Mallards Given Lead, Iron & Magnesium Dust
7		Missing
8	Jan-Mar 49	Domestic Mallards Given Luballoy Shot
9	Jan-Mar 49	Domestic Mallards Given Iron Shot
10	Jan-Mar 49	Domestic Mallards Given Variable Pellet Dosage
11	Jan-Mar 49	Retention Test - Variable Pellet Size - Wild Mallards
12	Jan-Mar 49	Domestic Mallards Given Lead & Iron Dust
13	Feb-Mar 49	Domestic Mallards Given Shot and Calcium Particles
14	Feb-Apr 49	Domestic Mallards Given Shot Containing .66% Calcium
15	Feb-Apr 49	Coontail Added to Domestic Mallard Diet (2 Exp.)
16	Feb-Apr 49	Test of Pick Up by Wild Mallards of 2% Mg. Shot
17	Apr-May 49	Effect of Egg Albumen & Corn Oil in D.M Diet
18	Apr-May 49	Fecundity & Fertility Test on Recovered Ducks
19	Apr-May 49	Wild Mallards Given Iron Shot (10 Pellets)
20	Apr-May 49	Domestic Mallards Given Pb-Sn-P Alloy Sh

Exp. No.	Period	Description of Experiment
21	Apr-May 49	Effect of Oyster Shell in Diet (D.M.)
22	May-Jun 49	Pick Up of Iron Shot by Wild Mallards
23	May-Jun 49	Domestic Mallards - Corn & Duckweed Diet
24	May-Jun 49	Domestic Mallards - Wild Seed Diet
25	May-Jun 49	Domestic Mallards - $CaCO_3$ Added to Corn Diet
26	May-Jun 49	Domestic Mallards - Ascorbic Acid Added to Corn Diet
27	Jun-Jul 49	Wild Mallards - Coontail Added to Corn Diet
28	Jun-Jul 49	Domestic Mallards - Tame Rice Diet
29	Jun-Jul 49	Domestic Mallards - Sage Pond Weed & Corn Diet
30	Jun-Jul 49	Domestic Mallards - Phosphate Powder Added to Corn Diet
31	Jul-Sep 49	Wild Mallards - Corn and Sage Pinweed Diet
32	Jul-Sep 49	Wild Mallards - Corn and Coontail Diet
33	Jul-Sep 49	Wild Mallards - Corn and Duckweed Diet
34	Jul-Sep 49	Wild Mallards - Charra &Corn Diet
35	Jul-Aug 49	Domestic Mallards - P and $CaCO_3$ Added to Corn Diet
36	Jul-Aug 49	Domestic Mallards - Test Effect of Previous Lead Dosage
37	Jul-Aug 49	Domestic Mallards - Effect of Age and Sex on Lead Poisoning
38	Oct-Dec 49	Blue Winged Teal - Variable Dosage - 1 to 4 Pellets
39	Oct 49-Jan 50	Wild Male Mallards Variable Dosage - 1-4 Pellets
40	Dec 49-Jan 50	Wild Female Mallards Variable Dosage - 1-4 Pellets

Exp. No.	Period	Description of Experiment
41	Dec 49-Jan 50	Wild Juvenile Mallard - 2% Mg. Shot - Coontail in Diet
42	Dec 49-Jan 50	Wild Adult Mallard - 2% Mg. Shot - Coontail in Diet
43	Jan-Feb 50	Compare Adult and Juvenile Wild Mallards
44	Jan-Feb 50	Wild Mallards - Corn, Rice & Seed Diet
45	Jan 50	1948 & 1949 Wild Mallards - Food Consumption & Weight Change
46	Jan-Feb 50	Wild Mallards - Influence Reduced Feeding
47	Jan-Feb 50	Wild Mallards - Mixed Seed Diet
48	Jan-Feb 50	Wild Mallards - Effect of Type Food on Weight
49	Mar-Apr 50	Domestic Mallards - Comparison of Whole and Ground Corn Diet
50	Apr-May 50	Domestic Mallards - Food Consumption - Variable Diets
51	Apr-Oct 50	Wild Mallards - Food & Grit Consumption
52	Apr-May 50	Wild Mallards - Food Consumption - Undosed
53	Apr-May 50	Wild Mallards - Food Consumption Dosed & Undosed
54	Apr-Jul 50	Wild Mallards - Influence of Diet on Recovery
55	Apr-Jul 50	Wild Mallards - Influence of Diet on Recovery
56	Jul 50	Domestic Mallards - Effect of Diet and Grit on Shot Erosion
57	Jul-Sep 50	Domestic Mallards - Experiment Not Clear
58	Aug-Oct 50	Domestic Mallards - Food Consumption
59	Aug-Oct 50	Domestic Mallards - Food Consumption
60	Nov-Dec 50	Wild Mallards - 1 Pellet Dosage Corn Diet

Exp. No.	Period	Description of Experiment
61	Nov-Dec 50	Wild Mallards - Coontail & Corn Diet (Controls 60)
62	Nov-Dec 50	Wild Mallards - Seed Diet
63	Nov-Dec 50	Wild Mallards - Corn Diet (Controls 60)
64	Nov-Dec 50	Wild Mallards - Mixed Diet (Controls 62)
65	Nov-Dec 50	Wild Mallards - Corn & Alfalfa Diet
66	Dec 50-Jan 51	Wild Mallards - Food Consumption & Weight Rice & Grain Diet
67	Feb-Mar 51	Wild Mallards - Food Consumption & Weight Grain Diet
68	Feb-Mar 51	Wild Mallards - Food Consumption & Weight Grain Diet
69	Feb-Mar 51	Wild Mallards - Food Consumption & Weight Grain Diet
60-69	Dec 50-Mar 51	Wild Mallards - Recovery of Ducks From Exp. 60-69 Inclusive
70	Feb-Mar 51	Game Farm Mallards - Drakes - Small Grain Diet - 1 Pellet
71	Feb-Mar 51	Game Farm Mallards - Hens - Small Grain Diet - 1 Pellet
72	Feb-Mar 51	Wild Mallards - Aspirator Test - Shot Recovery
73	Mar-Apr 51	Canada Geese - Variable Diet - 2 Pellets
74	Mar-Apr 51	Wild Mallards - Recovery of Lead & Iron Shot
75	Apr-Jun 51	Wild Mallards - Food Consumption & Shot Recovery
76	Apr-Jun 51	Wild Mallards - Latent Effects of Shot Dosage
77	Jul-Oct 51	Wild Mallards - Food Consumption - Variable Dosage History
78	Nov-Dec 51	Wild Mallards - Grain & Smartweed Diet 1 Pellet

Exp. No.	Period	Description of Experiment
79	Nov-Dec 51	Wild Mallards - Juvenile & Adult - Grain Diet - 1 Pellet
80	Nov-Dec 51	Wild Mallards - Juvenile & Adult - Wheat Diet - 1 Pellet
81	Jan-Feb 52	Wild Mallards - Excessive Dosage - 10 Pellets
82	Mar-Apr 52	Wild Mallards - Wheat Diet - 4 & 6 Pellets
83	Mar-Apr 52	Wild Mallards & Pintails - Food Consumption 2 Pellets
84	Mar-Aug 52	Bluebills - Diet Quohog Clam Meat & Oyster Shell
	Oct-Nov 49	(Not Numbered) Jar Experiment - Wild and Domestic Mallards - Shot Recovery

ILLINOIS NATURAL HISTORY SURVEY FILES

COVERING OLIN SPONSORED WORK IN PERIOD 1948-1953

II. Files on Reports, Data Sheets & Charts

File Designation	Description
A-Jordan Reports	Rough drafts of four reports (apparently never published) 1-The Influence of Diet in Lead Poisoning of Waterfowl 2-Effects of Lead Poisoning in Waterfowl 3-Symptoms and Lesions in Lead Poisoning of Waterfowl 4-The Fate of Pellets Ingested
B-Bellrose Reports	Two published reports and draft of report written after 1959. Publication uncertain. 1-Lead Poisoning Studies - August 1950 2-Effects of Ingested Lead Shot Upon Waterfowl Population 3-Lead Poisoning in Waterfowl (3 Drafts)
C-Miscellaneous Pre-1950 Publications	Includes following publications: 1-Dowdell & Green-1937; Lead-Magnesium Alloys for the Prevention of Lead Poisoning in Waterfowl 2-E.R. Kalmbach-1930-Report on Duck Mortality in Louisiana Lead Poisoning 3-E.R. Kalmbach-1935-Notes on Certain Experiments Dealing with Lead Poisoning Among Waterfowl 4-Neff & Sperry-1950-Lead Poisoning in Waterfowl-A Field Experiment
D-Experimental Summary Sheets	Tables summarizing description and results of following experiments: (a) - 1-10 inclusive (b) - 13-14-17 (c) - 19-28 inclusive (d) - 30-34 " (e) - 41-49 " (f) - 53-55 " (g) - 74-78 "
E-Tables and Charts-Drafts-Jordan	Drafts of tables and charts prepared by Jordan summarizing results. Intended for use in publications.
F-Tables and Charts-Finished-Jordan	Charts prepared by artist for inclusion in publications - No titles.
G-Charts-From Bellrose Publication	Originals of charts used by Bellrose in May 1959 publication.

- continued -

File Designation	Description
H-U.S. Weather Bureau Meteorological Summaries	Publications showing weather conditions in Peoria area during period experiments were conducted (1949-51)
I-Lead Analysis	Reports from Olin-East Alton Laboratories on lead analysis of duck bone and organs.
J-Food Analysis	Report from University of Illinois on chemical composition of various foods used in experiments.
K-Blood Analysis	Reports from College of Veterinary Medicine Univerity of Illinois
L-Working Papers	Rough Summary Sheets prepared by Jordan as working papers.
M-Post 1955 Correspondence	Miscellaneous reports and correspondence by Bellrose in period 1960-1965.

ILLINOIS NATURAL HISTORY SURVEY FILES

COVERING OLIN SPONSORED WORK IN PERIOD 1948-1953

III. HISTORY OF DUCKS USED IN EXPERIMENTS

N-1 - Wild Mallard Case Histories 1948-1950	Individual records of wild mallards picked up (some dead) or captured in field in 1948-1950 period.
N-2 Wild Mallard Case Histories 1948-1950	Same as N-1
O-Wild Mallards Chatauqua Refuge	Summary of examinations of wild mallards picked up alive and captured at Chatauqua in period 1948-1949
P-Game Farm Mallards	Weight changes and record of disposition of Game Farm Mallards used in 1949.
Q-Wild Mallards - Weight Records	Record of weights and shot in gizzard and body of ducks captured in February 1949.
R-Wild Mallards Escaped & Released	Individual records for mallards that escaped and were released from pens in winter of 1948-1949.
S-Wild Mallards Recovery Data	Records of ducks that recovered after lead dosage.
U-Wild Mallards - 1953	History and disposition of ducks in 1953.

BELLROSE DUCK TESTS

1949-1952

Summarized October 1974 (RSH)

	Ducks		Shot				30 Day Results Weight Loss %		Mortality %	
Exp. No.	Type	No.	Alloy	Size	Dose	Diet	Days	%	Days	%
4	WM	10	1.1% Mg	6	1	Corn	21	30	80	90
		10		6	2		21	36	60	100
		5		6	3		21	35	30	100
		5		6	4		14	43	14	100
		10	Controls	-	-		21	+2	--	---
6	WM	3	Pb-Mg Pieces	Equiv		Corn	20	36	20	100
		2	Pb Dust	4 #4			20	36	20	100
		2	Fe Dust				20	10	28	50
8	DM	3	Lubaloy	6	1	Corn	30	3.7	30	0
		3			3		30	16.5	30	33
		3			5		30	39.6	30	100
9	DM	10	Iron	6	6	Corn	30	6.8	30	10
10	DM	10	Lead	6	1	Corn	30	5.8	30	0
		10			2		30	38.8	30	40
		10			3		30	31.5	30	40
		10			4		30	42.3	30	90
		5			5		20	35.8	30	60
		5			6		20	43.4	30	80
		3			7		20	47.1	30	80
8,9 10	DM	10	Controls			Corn	30	2	30	0
11	WM	3	Lead	4	1	Corn	30	46	30	66
		3		6	1		30	40	30	66
		3		8	1		30	35	30	100
12	DM	3	Pb Dust 10/14	.67	Gms	Corn	21	34	30	100
		3	24/50				21	8	30	0
		3	100/150				21	7	30	0
		3	Fe Dust 10/14				21	0	30	0
		3	24/50				21	8	30	0
		3	100/150				21	6	30	0
13	DM	2	5% Ca-Pb in Pieces	.11 Gms.	1 #6	Corn	21	4	30	0
		2		.22	2 #6		21	22	30	50
		2		.33	3 #6		21	33	30	50
		2		.44	4 #6		21	20	30	50
		2		.66	6 #6		21	39	30	100
		2		.88	8 #6		21	31	30	50
		2		1.12	10 #6		21	39	30	100

							30 Day Results			
	Ducks			Shot			Weight Loss %		Mortality %	
Exp No.	Type	No.	Alloy	Size	Dose	Diet	Days	%	Days	%
14	DM	5	5% Ca-Pb	4	4	Mixed Grains	21	27	30	60
15	DM	10	Lead	6	4	Mixed Grain & Coontail	30	4	30	0
		5	Controls				30	6	30	0
15A	DM	10	Lead	6	8		30	11	30	0
			Controls				30	6	30	0
17	DM	10	Lead	6	4	Corn, Corn Oil & Egg Albumen	30	23	30	20
			Controls				30	5	30	0
19	WM	10	Iron	6	10	Mixed Grain	30	+1	30	0
		5	Controls				30	+1	30	0
20	DM	10	P-Sn-Pb	6	6	Mixed Grain	30	43	30	80
		5	Controls				30	13	30	0
21	DM	5	Lead	6	4	Corn&Oyster Shell	30	18	30	20
		5	Lead	6	8		30	23	30	20
		5	Controls				30	9	30	0
23	DM	10	Lead	6	4	Corn	30	43	30	70
		10	Lead	6	4	Corn&Duckweed	30	8	30	20
		10	Lead	6	8		30	10	30	20
		5	Controls				30	+4	30	0
24	DM	10	Lead	6	4	Weed Seed (Smartweed, Pondweed, Millet)	30	19.3	30	20
		10	Lead	6	4	Corn	30	43	30	70
		5	Controls			Weed Seed	30	6	30	0
25	DM	10	Lead	6	4	Corn	30	43	30	70
		10	Lead	6	4	Corn&$CaCO_3$	30	20	30	20
		10	Lead	6	8		30	35	30	60
		5	Controls				30	5	30	0
26	DM	10	Lead	6	4	Corn	30	43	30	70
		10	Lead	6	4	Corn&Vit.C Ascorbic Acid	30	37	30	40
				6	8		30	46	30	60
		5	Controls				30	16	30	0
27	WM	10	Lead	6	8	Corn&Coontail	30	43	30	90
		5	Controls				30	+1	30	0
28	DM	10	Lead	6	4	Tame Rice	30	10	30	20
		5	Controls				30	2	30	0
29	DM	5	Lead	6	4	Corn&Sage Pondweed	30	+3	30	0
		3	Controls				30	10	30	0

	Ducks		Shot				30 Day Results			
							Weight Loss %		Mortality %	
Exp. No.	Type	No.	Alloy	Size	Dose	Diet	Days	%	Days	%
30	DM	10	Lead	6	4	Corn & Phosphorous Powder	30	17	30	20
		5	Controls				30	2	30	0
31	WM	10	Lead	6	4	Corn & Sage Pondweed	30	28	30	60
		5	Controls				30	2	30	0
32	WM	5	Lead	6	4	Corn & Coontail	30	38	30	60
		5	Controls				30	+11	30	0
33	WM	5	Lead	6	4	Corn & Duckweed	30	29	30	60
		5	Controls				30	+6	30	0
34	WM	10	Lead	6	4	Corn & Charro	30	36	30	70
			Controls				30	2	30	0
35	DM	10	Lead	6	4	Corn & $CaCO_3$ & P	30	34	30	40
		10	Controls				30	13	30	0
36	DM	10	Lead No previous dosage	6	4	Mixed Grains	30	30	30	30
	DM	10	Lead Previous dosage	6	4	Mixed Grains	30	24	30	20
	DM		Controls Previous dosage			Mixed Grains	30	16	30	0
37	DM	5	Lead Adult Males	6	8	Mixed Grains	30	27	30	60
	DM	5	Lead Adult Females	6	8	Mixed Grains	30	38	30	60
	DM	5	Lead 8 Week Males	6	8	Mixed Grains	30	2	30	0
	DM	5	Lead 8 Week Females	6	8	Mixed Grains	30	4	30	0
	DM	5	Lead 5 Week Males	6	8	Mixed Grains	30	8	30	20
	DM	5	Lead 5 Week Females	6	8	Mixed Grains	30	25	30	40
	DM	5	Controls Adult Males			Mixed Grains	30	-6	30	0

	Ducks		Shot				30 Day Results			
							Weight Loss %		Mortality %	
Exp. No.	Type	No.	Alloy	Size	Dose	Diet	Days	%	Days	%
37	DM	5	Controls Adult Fem.			Mixed Grains	30	-9	30	0
	DM	5	Controls 8 Week Males				30	+3	30	0
	DM	5	Controls 8 Week Fem.				30	-3	30	0
	DM	5	Controls 5 Week Males				30	+4	30	0
	DM	5	Controls 5 Week Fem.				30	+8	30	0
38	Blue Winged Teal	10	Lead	6	1	Mixed Grains & Coontail	30	30	30	40
		10			2		30	36	30	40
		10			3		30	36	30	60
		10			4		30	39	30	70
			Controls				30	17	30	30
39	WM Male	10	Lead	6	1	Mixed Grains &Coontail	30	-3	30	0
		10			2		30	23	30	50
		10			3		30	8	30	20
		10			4		30	26	30	70
		10	Controls				30	-3	30	0
40	WM Female	10			1	Mixed Grains & Coontail	30	7	30	20
		10			2		30	28	30	80
		10	Controls				30	+10	30	0
41	WM Female	5	2% Mg	8	1	Mixed Grains & Coontail	14	+2	30	0
		10		8	2		14	+2	30	0
		5	Controls				14	-1	30	0

Note: X-Rays showed essentially all lead out of system in 2 weeks.

Exp. No.	Type	No.	Alloy	Size	Dose	Diet	Days	%	Days	%
42	WM	10	2% Mg	8	1	Mixed Grains	15	23	15	10
							30	37	30	80
			Controls				30	0	30	0

Note: X-Rays showed pellets failed to pass in ducks that died.

Exp. No.	Type	No.	Alloy	Size	Dose	Diet	Days	%	Days	%
43	WM Juv	10	Lead	6	1	Mixed Grains	30	29	30	60
			Controls				30	10	30	10
	WM Adult	10	Lead	6	1		30	34	30	80
			Controls				30	3	30	10
44	WM Male	10	Lead	6	1	1/3 Corn 1/3 Rice 1/6 Millet 1/6 Smartweed	20	35	20	60
			Controls				20	5	20	0
47	WM	10	Lead	6	1	2 Wks Weed Seeds-2 Wks Mixed Grains	30	30	30	60
			Controls				30	3	30	0

	Ducks		Shot				30 Day Results			
							Weight Loss %		Mortality %	
Exp. No.	Type	No.	Alloy	Size	Dose	Diet	Days	%	Days	%
49	DM	10	Lead	6	4	Whole Yellow Corn	30	38	30	70
				6	4	Ground Corn	30	33	30	60
			Controls			Whole Corn	30	4		
						Ground Corn	30	4		
55	DM	5	Lead	6	4	Duck Pellets	30	25	30	40
60	WM	10	Lead	4	1	Corn	30	40	30	60
			Controls				30	+5	30	0
61	WM	10	Lead	4	1	Corn & Coontail	30	30	30	40
			Controls				30	+4		
62	WM	10	Lead	4	1	Grain, 70% Seeds, 10% Rice, 20%	30	3	30	30
			Controls				30	4	30	0
63	WM	10	Lead	6	1	Corn	30	30	30	70
			Controls-Exp. 60							
64	WM	10	Lead	6	1	Grain, 70% Rice, 20% Smartweed,10%	30	10	30	10
			Controls-62							
65	WM	10	Lead	6	1	Corn & Alfalfa	30	30	30	40
			Controls				30	1	30	20
66	WM Drakes	10	Lead	6	1	80% Grain 20% Rice	30	13	30	10
			Controls			Feed Same as Dosed	30	17	30	10
			Controls			Unlimited Food	30	1	30	0
67	WM Hens	10	Lead	6	1	Small Grain	30	28	30	50
			Controls			Food Qty.Same as Dosed Birds	30	30	30	70
			Controls				30	+1	30	0
68	WM Drakes	10	Lead	6	1	Small Grain	30	18	30	10
			Controls				30	0	30	0
69	WM Hens	10	Lead	6	1	Small Grain	30	29	30	50
			Controls				30	+1	30	0
70	DM Drakes	10	Lead	6	1	Small Grain	30	2	30	0
		5	Controls				30	1	30	0

	Ducks		Shot				30 Day Results			
							Weight Loss %		Mortality %	
Exp. No.	Type	No.	Alloy	Size	Dose	Diet	Days	%	Days	%
71	DM	10	Lead	6	1	Small Grain	30	+1	30	0
	Hens	5	Controls				30	-6	30	0
72	WM	15	Lead	6	2	Small Grain	30	20	30	33
	Drakes		Controls-68				30	0	30	0
73	Can.	8	Lead	4	2					
	Geese									
74	WM	5	Lead	6	2	Small Grain	30	34	30	60
	Drakes									
75	WM	10	Lead	6	1	Small Grain	30	36	30	200
	Drakes								60	50
		10	Controls				30	9	30	0
	Hens	10	Lead	6	1		30	32	30	20
									60	20
			Controls				30	4	30	0
78	WM	20	Lead (1)	4	1	Small Grain	21	11	21	10
	Drakes	20	Lead (2)	6	1	75%-Smart-	21	+5	21	0
		15	Controls (3)			weed 25%	21	+5	21	0
			Food Consumption:		(1)	.091 per day				
					(2)	.182 per day				
					(3)	.201 per day				
79	WM	10	Lead	6	1	Small Grain	21	2	21	20
	Adult	10	Controls				21	+28	21	0
	Drakes									
	WM	10	Lead	6	1		21	+22	21	0
	Juv.	10	Controls				21	+30	21	0
	Drakes									

Note: Ducks lost 15% at start of experiment.

Exp. No.	Type	No.	Alloy	Size	Dose	Diet	Days	%	Days	%
80	WM	10	Lead	6	1	Wheat	21	-18	21	10
	Adult	10	Controls				21	-1	21	0
	Drakes									
	WM	10	Lead	6	1	Wheat	21	-27	21	20
	Juv.		Controls				21	-2	21	0
	Drakes									
81	WM	7	Lead	6	10	Wheat	9	17	9	70
	Adult	7	Controls				14	3	14	0
	Drakes									
82	WM	10	Lead	6	4	Wheat	30	22	30	20
	Adult	7	Lead	6	6	Wheat	30	24	30	15
	Drakes		Controls - Exp. 83							

							30 Day Results			
	Ducks		Shot				Weight Loss %		Mortality %	
Exp. No.	Type	No.	Alloy	Size	Dose	Diet	Days	%	Days	%
83	WM Adult Drakes	10	Lead	6	2	Wheat	30	34	30	40
			Controls				30	+10	30	0
	Pintails Adult Drakes	10	Lead	6	2	Wheat	30	37	30	70
			Controls				30	+7	30	0
84	Blue-bills Adult Drakes	10	Lead	6	2	Quohog Clam Meat &Oyster Shells	30	-3	30	0
		10	Controls				30	-15	30	0

UNIVERSITY OF ILLINOIS-URBANA
598.4H73L C001
LEAD POISONING IN WATERFOWL S.L
3 0112 017656080